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Associations between anthropometric indicators and both refraction and ocular biometrics in a cross-sectional study of Chinese schoolchildren

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ABSTRACT

Objective To identify associations between anthropometric indicators (height, weight and body mass index (BMI)) and both refraction and ocular biometrics in Chinese schoolchildren in Tianjin, China.

Design Cross-sectional study.

Participants A total of 482 (86.07%) students (6–15 years old) with no history of ocular or systemic pathologies were enrolled in this study.

Methodology Height and weight were measured using standardised protocols. Ocular biometrics (axial length (AL), vitreous chamber depth (VCD) and corneal curvature (CC)) were measured by a low-coherence optical reflectometry device. Cycloplegic refraction was measured using autorefraction. The AL/CC ratio and spherical equivalent refraction (SER) were calculated. Myopia was defined as SER ≤−0.50 dioptres (D). Multiple linear regression analysis was performed to explore the associations between anthropometric indicators (height, weight and BMI) and both refraction and ocular biometrics.

Results The overall prevalence of myopia was 71.16%. Overall, only height was associated with ALs, VCDs, AL/CC ratios and refractions after controlling for age, gender, parental myopia, family income, reading and writing distance and time spent outdoors. Furthermore, age-specific results demonstrated that height and weight were independently associated with refraction in participants aged 6–8 years and 9–11 years participants. Higher heights in schoolchildren were associated with longer ALs (regression coefficient b=+0.25 for each 10 cm difference in height, p<0.01), deeper VCDs (b=+0.23, p<0.01), higher AL/CC ratios (b=+0.04, p<0.01) and more negative refractions (b=−0.48, p<0.01). Heavier weights were also associated with longer ALs (+0.29 mm, p<0.01), deeper VCDs (+0.29 mm, p<0.01), higher AL/CC ratios (+0.04, p<0.01) and more negative refractions (−0.48 D, p<0.01).

Conclusions Height and weight remained independently related to refraction and various ocular biometrics during the early adolescent growth period after adequately controlling for covariates, which could support the idea that a shared mechanism may regulate the coordinated growth of body and eye size in children.

Strengths and limitations of this study

- The study participants were schoolchildren ranging in age from 6 to 15 years old, a period when myopia commonly develops, which could allow us to study the association between body stature and refraction during development.
- The overall and age-specific associations between anthropometric indicators and both refraction and ocular biometrics were calculated in this study to help better clarify the coordinated growth of body and eye size.
- Ocular biometrics were measured comprehensively, and the covariates were adequately controlled, which allowed us to achieve a more detailed analysis.
- An evaluation of causality was not possible because this study had a cross-sectional design.

INTRODUCTION

Myopia has reached almost epidemic proportions in the world, especially in certain areas of East and Southeast Asia.[1] This condition is commonly viewed as aetiologically heterogeneous. Genetic and environmental risk factors are involved in its progression. The genetic basis of myopia has been supported by evidence indicating high heritability values in twin studies[2] and a higher prevalence of myopia in children with myopic parents.[3] Excessive near work activities,[4 5] limited time spent outdoors[6 7] and intensive educational pressure[8 9] reportedly to promote the development of myopia. In our effort to consider other factors, we noted that anthropometric indicators, such as height, are thought to be associated with refraction, although no consensus has been achieved regarding this issue.[10 11]

Refractive status is determined by the balance of the refractive power of the cornea and lens and the axial length (AL) of the eye (representing the combination of anterior chamber depth (ACD), lens thickness (LT) and vitreous chamber depth (VCD)).[12] Myopia usually arises in an eye that has become too long, particularly via vitreous chamber elongation. Several epidemiological studies have demonstrated that changes in ocular dimensions that occur in early life progress concomitant with physical development in children,[13 14] and the ages of cessation are also similar for increases in height and axial elongation.[13] Furthermore, genetic studies have confirmed that a common genetic pathway underlies both height and AL,[15 16] although no specific genetic variants have yet been identified. All of these clues suggest a shared mechanism that regulates the coordinated growth of body and eye size. It has been suggested that there may be a relationship between body stature and refraction. However, in contrast to the consensus regarding the significant associations between body stature and AL, the relationship between body stature and refraction remains controversial. Although many studies have reported that taller[10 17–20] and heavier persons[21 22] have an increased likelihood of having myopia, other studies have found no such association.[23–28] The discrepancies among these studies may be due to differences in sample sizes, concept definitions or other methodological variations (eg, height and weight obtained via self-reporting).

In China, few studies have comprehensively measured ocular biometrics or further explored their associations with body stature. Additionally, myopia most commonly starts in young schoolchildren and progresses in early adolescence.[21] Therefore, it is most appropriate to study the effect of body growth on refractive development in young, growing students. In the current survey, we explored the associations between anthropometric indicators, including height, weight and body mass index (BMI), and both refraction and ocular biometrics in schoolchildren aged 6–15 years old in Tianjin, China.

METHODS

Recruitment

Participants were recruited based on the following strategies. Two districts were randomly chosen from the six main urban districts in Tianjin in November 2016. Next, one primary school and one junior high school were randomly selected from each selected district. Then, one class was randomly chosen from each grade level within the two selected schools. All students in these selected classes were invited, but participation in this study was voluntary. After the purposes and procedures of the study were explained to each student and their parents in depth, written informed consent was collected. Students without parental consent and students who had amblyopia, heterotropia or any ocular or systemic pathologies were excluded.

The study protocol was performed in accordance with the tenets of the Declaration of Helsinki.

Ocular examinations

All participants underwent a comprehensive eye examination, including measurements of intraocular pressure, a slit-lamp examination of the anterior and posterior segments, cycloplegic autorefraction and ocular biometrics. The purpose of intraocular pressure measurement and slit-lamp examination was to exclude contraindications for mydriasis.

Ocular biometrics, such as AL, central corneal thickness (CCT), ACD, LT, VCD and corneal curvature (CC), were measured with a low-coherence optical reflectometry device (Lenstar LS900; Haag-Streit AG, 3098 Koeniz, Switzerland) in both eyes before pupil dilation. In addition, the AL/CC ratio, also commonly known as the axial length/corneal radius ratio, was calculated. Then, cycloplegia was induced by administering one drop containing 0.5% tropicamide and 0.5% phenylephrine in a mixed eye agent to each eye at 0 min and 5 min. Twenty-five minutes after the second instillation, pupillary dilation and the pupillary light reflex were evaluated. Full cycloplegia was considered when the pupil diameter reached 6 mm or more and the light reflex disappeared. A third drop was administered if full cycloplegia was not achieved. Then, participants with full cycloplegia underwent autorefraction using an auto-kerato-refractor (Canon Autorefractor RK-F1, Tokyo, Japan), and three consecutive measurements were taken in both eyes. The mean value of three valid measurements was calculated for statistical analysis. All of the above instruments were calibrated before the ocular examination. All examinations were performed by board-certified ophthalmologists and certified optometrists.

Definitions

The spherical equivalent refraction (SER) of each eye was calculated as the spherical refraction +1/2 of the cylindrical refraction using data obtained using the autorefractor. Myopia was defined as an SER of ≤−0.5 dioptre (D).

Anthropometric measurements

Height and weight were obtained following specific standardised protocols[29] and measured by community doctors on the students' campus. Height was determined with the subject standing barefoot on the base of the height metre and recorded in centimetres (cm). Weight was measured without shoes and heavy coats on a calibrated electronic weighing scale and recorded in kilograms (kg). BMI was calculated as weight/height and recorded in kilograms per square metre (kg/m^2).

Questionnaire

The parents of participants and those excluded were all asked to complete a questionnaire developed to collect information on social-demographic characteristics and potential risk factors for school myopia (online supplementary table 1).

The basic characteristics of the participants included age, gender, the monthly income of the family and the number of parents with myopia. Near-work-related behaviours were ascertained with the question 'What is the distance between your child's eyes and a book when reading or writing?', with answers categorised as follows: <10 cm, 10–19 cm, 20–29 cm and ≥30 cm. Time spent outdoors was estimated by asking how many hours per day the child spent on outdoor activities during weekdays and weekends separately. The average time spent outdoors was calculated by the following formula: [$T_{weekday}$ (hours spent on weekdays)×5 + $T_{weekend}$ (hours spent on weekends)×2] ÷ 7.

Statistical analysis

Because refraction and ocular biometrics were highly correlated between two eyes (the Pearson correlation coefficients (r) for refraction, AL, CCT, ACD, LT, VCD, CC and AL/CC ratio were 0.90, 0.96, 0.89, 0.93, 0.93, 0.95, 0.97 and 0.95, respectively, and all p values were lower than 0.01), the data obtained from the right eye were chosen for analyses. Ocular biometrics were all normally distributed, as determined by P–P plots.

T-tests were performed for quantitative variables, and χ^2 tests were performed for categorical variables to analyse the differences in basic characteristics between individuals with and without myopia. Univariate associations between anthropometric indicators and both refraction and ocular biometrics were identified. Simple linear regression models were constructed to assess the effects of height, weight and BMI (as independent variables) on refraction and individual ocular biometrics (as dependent variables). Tests for linear trends were performed by entering the median value of each category of the anthropometric indicator based on quartiles as a continuous variable into the models. Multiple linear regression models were then fitted after adjusting, in turn, for age and gender or for age, gender, parental myopia, family income, reading and writing distance and time spent outdoors. In addition, all participants were divided into the following age groups: 6–8 years old, 9–11 years old and 12–15 years old. The results of age-specific associations of anthropometric indicators with both refraction and ocular biometrics after controlling for the above covariates were calculated. Collinearity diagnostics were performed, and multicollinearity was absent among the independent variables used in each model.

Statistical analyses were performed using commercial statistical software (SPSS for Windows, V.20.0), and p values <0.05 were considered statistically significant.

Patient and public involvement

Patients and the public were not involved in developing the research questionnaire, outcome measures or overall design of this study protocol.

RESULTS

Participant characteristics

Among 560 students who were initially invited, a total of 482 participants ranging in age from 6 to 15 years old were available for statistical analysis after excluding 70 students without parental consent, 5 students with heterotropia and 3 students with amblyopia. The response rate in this study was 86.07% (482 of 560). Individuals who were included were older (9.42±2.09 vs 7.60±2.38 years old, p<0.01) than those who were excluded. There were no significant differences in gender, parental myopia, monthly family income, reading and writing distance and time spent outdoors between included and excluded individuals.

The overall prevalence of myopia was 71.16% (343 of 482; 95% CI 67.01% to 75.10%). The mean SER, height, weight and BMI of all participants was −1.48±1.82 D, 140.79±13.95 cm, 38.29±10.86 kg and 19.04±3.18 kg/m^2, respectively (table 1). Participants with myopia were older, taller and heavier. These individuals were more likely to have myopic parents, a higher monthly family income, a closer reading and writing distance and to spend less time outdoors. Moreover, these participants had eyes with longer ALs, deep ACDs and VCDs, thinner LTs and larger AL/CC ratios (all p values were less than 0.05).

Bivariate correlations between variables

Bivariate correlations of body stature with both refraction and ocular biometrics are presented in table 2, which was of low to moderate strength. For example, height was positively correlated with AL (r=0.50, p<0.01), CCT (r=0.17, p<0.01), ACD (r=0.29, p<0.01), VCD (r=0.49, p<0.01) and the AL/CC ratio (r=0.49, p<0.01) and negatively correlated with SER (r=−0.45, p<0.01) and LT (r=−0.24, p<0.01).

Linear trends in refraction and ocular biometrics changes by body stature quartiles

Taller and heavier individuals tended to have eyes with longer ALs, thicker CCTs, deeper ACDs, thinner LTs, deeper VCDs, higher AL/CC ratios and more myopic refractions (all p values for trend were less than 0.05) (table 3). In addition to ACD and LT, the above tendencies were also observed among more obese schoolchildren (students with higher BMIs).

Linear regression analysis of the associations between anthropometric indicators and both refraction and ocular biometrics

In model 1, we used the association between height and refraction as an example and found that for each 10 cm increase in height, the SER was expected to decrease by 0.59 D (p<0.01) without controlling for any covariates (table 4). In the next two models, we controlled, in turn, for age and gender or for age, gender, parental myopia, family income, reading and writing distance and time spent outdoors. The difference in SER declined by 0.26 D (p<0.01) and 0.21 D (p<0.05) in models 2 and 3, respectively. In general, higher heights were associated with longer ALs (+0.14 mm, p<0.05), deeper VCDs (+0.13 mm, p<0.05), greater AL/CC ratios (+0.02, p<0.05) and more negative refractions (−0.21 D, p<0.05) among participants aged 6–15 years. Nonetheless, weight and BMI were not

Table 1 Summary of the characteristics of the participants

	Total	Myopia	Non-myopia	P value
Age (years)	9.42±2.09	9.88±2.14	8.30±1.45	<0.01
Male	264 (54.77)	187 (54.52)	77 (55.40)	0.86
Female	218 (45.23)	156 (45.48)	62 (44.60)	0.86
Parental myopia*				<0.01
None	129 (28.48)	74 (23.13)	55 (41.35)	
One parent	188 (41.50)	134 (41.88)	54 (40.60)	
Both parents	136 (30.02)	112 (35.00)	24 (18.05)	
Monthly family income*				<0.05
<4000 RMB	41 (8.78)	27 (8.16)	14 (10.29)	
4000–8000 RMB	136 (29.12)	89 (26.89)	47 (34.56)	
8000–10 000 RMB	133 (28.48)	89 (26.89)	44 (32.35)	
10 000–15 000 RMB	91 (19.49)	73 (22.05)	18 (13.24)	
≥15 000 RMB	66 (14.13)	53 (16.01)	13 (9.56)	
Reading and writing distance*				<0.05
<10 cm	45 (9.62)	36 (10.81)	9 (6.67)	
10–20 cm	200 (42.74)	148 (44.44)	52 (38.52)	
20–30 cm	166 (35.47)	117 (35.14)	49 (36.30)	
≥30 cm	57 (12.18)	32 (9.61)	25 (18.52)	
Time spent outdoors (hours)	1.20±0.70	1.16±0.70	1.31±0.69	<0.05
Height (cm)	140.79±13.95	143.85±14.17	133.22±10.01	<0.01
Weight (kg)	38.29±10.86	40.06±11.05	33.92±9.01	<0.01
BMI (kg/m^2)	19.04±3.18	19.10±3.14	18.89±3.28	0.52
SER (D)	−1.48±1.82	−2.20±1.66	0.30±0.54	<0.01
AL (mm)	23.81±1.12	24.16±1.07	22.95±0.72	<0.01
CCT (µm)	547.65±32.44	548.88±33.32	544.63±30.05	0.19
ACD (mm)	3.08±0.26	3.14±0.25	2.94±0.23	<0.01
LT (mm)	3.47±0.20	3.43±0.20	3.55±0.19	<0.01
VCD (mm)	17.27±1.09	17.60±1.05	16.46±0.71	<0.01
CC (mm)	7.78±0.26	7.78±0.25	7.79±0.26	0.84
AL/CC ratio	3.06±0.13	3.11±0.13	2.95±0.07	<0.01

Data are presented as the means with SD or as n (%).
*Numbers of individuals vary due to missing data.
ACD, anterior chamber depth; AL, axial length; BMI, body mass index; CC, corneal curvature; CCT, central corneal thickness; LT, lens thickness; SER, spherical equivalent refraction; VCD, vitreous chamber depth.

correlated with refraction in our multiple linear regression models.

Furthermore, the participants were categorised into the following age groups: 6–8 years old (n=170), 9–11 years old (n=158) and 12–15 years old (n=154). After controlling for the above covariates, the age-specific associations were calculated (table 5). Both height and weight remained independently associated with refraction in the age range from 6–8 years old to 9–11 years old. Particularly from 9 to 11 years old, higher heights in schoolchildren were associated with longer ALs (+0.25 mm, p<0.01), deeper VCDs (+0.23 mm, p<0.01), higher AL/CC ratios (+0.04, p<0.01) and more negative refractions (−0.48 D, p<0.01) in their eyes. Heavier weights were also associated with longer ALs (+0.29 mm, p<0.01), deeper VCDs (+0.29 mm, p<0.01), higher AL/CC ratios (+0.04, p<0.01) and more negative refractions (−0.48 D, p<0.01). However, from 12 to 15 years of age, no association was detected between body stature and refraction.

DISCUSSION

In this paper, we comprehensively measured ocular biometrics and then explored the overall and age-specific associations between anthropometric indicators and

Table 2 Bivariate correlations of body stature with refraction and ocular biometrics

	Height (cm)	Weight (kg)	BMI (kg/m^2)
SER (D)	−0.45**	−0.39**	−0.11*
AL (mm)	0.50**	0.45**	0.15*
CCT (µm)	0.17**	0.19**	0.09*
ACD (mm)	0.29**	0.22**	0.03
LT (mm)	−0.24**	−0.19**	−0.04
VCD (mm)	0.49**	0.44**	0.16**
CC (mm)	0.07	0.10*	0.08
AL/CC ratio	0.49**	0.40**	0.10*

Data are the Pearson correlation coefficients.
**P<0.01.
*P<0.05.
ACD, anterior chamber depth; AL, axial length; BMI, body mass index; CC, corneal curvature; CCT, central corneal thickness; LT, lens thickness; SER, spherical equivalent refraction; VCD, vitreous chamber depth.

both refraction and ocular biometrics after adequately controlling for covariates among 6- to 15-year-old schoolchildren. In China, few studies such as this one have been conducted. Wang *et al*[14] confirmed a positive association between height and AL in schoolchildren aged 7–15 years based on longitudinal data obtained in Guangzhou, China. However, detailed information about the associations between body stature and refraction and other ocular biometrics was not available in that study. Therefore, compared with previous studies,[14 28] the present study achieved a more detailed analysis.

The current results are in almost complete agreement with those of Saw *et al*,[17] who showed that among 1449 Singaporean Chinese children aged 7–9 years old, taller individuals were more likely to have eyes with longer ALs (+0.46 mm, p<0.01), deeper VCDs (+0.46 mm, p<0.01), flatter corneas (+0.10 mm, p<0.01), greater AL/CC ratios (+0.02, p=0.03) and refractions that trended towards myopia (−0.47 D, p<0.01) after controlling for age, gender, parental myopia and the number of books read per week. A birth cohort performed in Britain to examine the relationship between height growth trajectories and the development of myopia presented similar results.[10] For each SD increase in height for children aged from 2.5 years old to 10 years old, SER became more negative by −0.075 D (95% CI −0.112 to −0.039; p<0.01) and −0.081 D (95% CI −0.129 to −0.034; p<0.01) when the children reached 11 and 15 years old, respectively. However, Huang *et al*[28] reported that no significant correlation between myopia shift and height changes among schoolchildren aged 7–9 years old in Taiwan, China.

Although the association remains unclear, these results will help us to further explore the intricate relationship between the development of physical characteristics and refraction. A commonly proposed explanation for this potential association is that both higher height and myopia are independent consequences of better socioeconomic status; therefore, there may be no causal relationship between height and myopia.[17 23] However, in this study, after we controlled for socioeconomic characteristics and myopia-related risk factors, height remained independently related to refraction and various ocular biometrics. Myopia most commonly develops during the period from childhood to early adolescence (from approximately 8–14 years old),[30] and growth spurts also occur in this period.[31] The early period of adolescence is mainly characterised by growth spurts and the onset of sexual development, which lasts for approximately 2 or 3 years.[32] The age range of early adolescence is approximately 8–11 years old. Therefore, we inferred that the development of refraction could be related to physical development during the early period of adolescent growth. The findings of the Singapore Cohort Study of Risk Factors for Myopia (SCORM) support this hypothesis.[19] SCORM reported that boys and girls who experienced earlier peak height velocity also achieved earlier peak SER velocity (at a mean age of 10.1 vs 10.6 years old for boys, p=0.01, and 10.0 vs 10.6 years old for girls, p=0.01) and had an earlier age of onset of myopia (9.9 vs 10.4 years old for boys, p=0.03, and 9.7 vs 10.1 years old for girls, p=0.04). The exact biological pathways underlying these associations are currently unknown. Some major systemic hormones, such as growth hormone, thymic hormone and insulin-like growth factors, reportedly could regulate longitudinal bone growth during childhood, which are also involved in the development of experimental myopia.[33 34] In addition, epidemiological studies reported that children with growth hormone deficiency have shorter body stature and ALs than usual.[35] Growth hormone supplementation in these children could partially bring the stature and ALs back within the normal range.[36] Sex hormones may be another significant mediator during puberty,[37] but our age-specific results (no association was detected in participants aged12–15 years) may not support this idea. Although these hormones were not determined in this cross-sectional study, we believe that the shared mechanism between height and refraction may shed new light on the aetiology of myopia and the efforts to explore the effect of endocrine traits observed during childhood and adolescence on body and eye size in the future studies.

The relationships weight and BMI share with refraction are not as extensively studied as those with height, but the findings regarding these relationships are also inconclusive. Heavier and more obese Chinese children and adults in Singapore have refractions that trend towards hyperopia.[17 23] Moreover, heavier adults in rural Myanmar reportedly have more positive refractions.[25] However, a cross-sectional study performed in 19-year-old male conscripts in South Korea found that weight and BMI had no effect on refraction.[27] Consistent with the results of a twin study performed in Australia,[22] in our study, heavier weights were associated with more

Table 3 Unadjusted mean values of refraction and ocular biometrics by quartiles of height, weight and BMI

	Range	n	SER (D)	AL (mm)	CCT (μm)	ACD (mm)
Height (cm)						
1st quartile	100.0~130.0	127	−0.48±1.13*	23.09±0.78	542.11±30.93	2.97±0.24
2nd quartile	130.1~140.0	136	−1.08±1.46	23.58±0.98	544.96±32.69	3.05±0.28
3rd quartile	140.1~150.7	99	−1.86±1.80	24.15±1.01	550.04±32.31	3.16±0.23
4th quartile	150.8~182.5	120	−2.68±2.06	24.56±1.14	554.58±32.76	3.18±0.22
P for trend†			P<0.01	P<0.01	P<0.05	P<0.01
Weight (kg)						
1st quartile	20.0~30.0	129	−0.59±1.19	23.19±0.80	541.27±32.75	3.02±0.26
2nd quartile	30.1~36.1	112	−1.12±1.30	23.58±1.00	547.64±31.34	3.04±0.26
3rd quartile	36.2~45.0	128	−1.75±1.92	24.02±1.12	544.17±31.56	3.12±0.24
4th quartile	45.1~82.3	113	−2.54±2.14	24.52±1.12	558.92±31.65	3.16±0.24
P for trend			P<0.01	P<0.01	P<0.01	P<0.01
BMI (kg/m^2)						
1st quartile	14.0~16.5	121	−1.19±1.62	23.55±1.05	543.79±31.55	3.09±0.25
2nd quartile	16.6~18.4	120	−1.39±1.69	23.80±1.14	545.79±32.26	3.05±0.28
3rd quartile	18.5~20.8	120	−1.59±1.88	23.90±1.12	547.12±32.16	3.09±0.25
4th quartile	20.9~30.6	121	−1.74±2.05	24.00±1.16	533.90±33.26	3.11±0.25
P for trend			P<0.05	P<0.01	P<0.05	P=0.32

	Range	n	LT (mm)	VCD (mm)	CC (mm)	AL/CC ratio
Height (cm)						
1st quartile	100.0~130.0	127	3.55±0.19	16.57±0.74	7.75±0.25	2.98±0.09
2nd quartile	130.1~140.0	136	3.48±0.23	17.07±0.96	7.79±0.27	3.03±0.11
3rd quartile	140.1~150.7	99	3.42±0.18	17.58±0.99	7.81±0.26	3.09±0.13
4th quartile	150.8~182.5	120	3.41±0.19	17.97±1.12	7.78±0.25	3.16±0.14
P for trend			P<0.01	P<0.01	P=0.36	P<0.01
Weight (kg)						
1st quartile	20.0~30.0	129	3.51±0.20	16.64±0.77	7.75±0.25	2.99±0.10
2nd quartile	30.1~36.1	112	3.49±0.21	17.07±0.97	7.78±0.28	3.03±0.11
3rd quartile	36.2~45.0	128	3.45±0.21	17.46±1.10	7.80±0.24	3.08±0.13
4th quartile	45.1~82.3	113	3.40±0.19	17.95±1.08	7.81±0.25	3.14±0.15
P for trend			P<0.01	P<0.01	P=0.08	P<0.01
BMI (kg/m^2)						
1st quartile	14.0~16.5	121	3.45±0.18	17.01±1.05	7.73±0.26	3.05±0.12
2nd quartile	16.6~18.4	120	3.51±0.23	17.23±1.04	7.81±0.26	3.05±0.13
3rd quartile	18.5~20.8	120	3.46±0.20	17.38±1.11	7.81±0.26	3.06±0.14
4th quartile	20.9~30.6	121	3.44±0.20	17.46±1.13	7.79±0.24	3.08±0.14
P for trend			P=0.37	P<0.01	P=0.19	P<0.05

*Data are expressed as means±SD.
†Tests for linear trend is performed by entering the median value of each category of the anthropometric indicator as a continuous variable in the models.
ACD, anterior chamber depth; AL, axial length; BMI, body mass index; CC, corneal curvature; CCT, central corneal thickness; LT, lens thickness; SER, spherical equivalent refraction; VCD, vitreous chamber depth.

negative refractions among participants aged 6–8 and 9–11 years old.

This study has several limitations that warrant consideration. First, information on putative myopia risk factors obtained from our questionnaire (eg, the distance between the child's eyes and a book when reading or writing) was subjectively estimated by the parents. Although this method has been widely applied in

Table 4 Multiple linear regression models of refraction and ocular biometry by height, weight and BMI

	Model 1	P value	Model 2	P value	Model 3	P value
Height (per 10 cm)						
SER (D)	−0.59 (−0.70 to −0.49)*	<0.01	−0.26 (−0.45 to −0.08)	<0.01	−0.21 (−0.40 to −0.01)	<0.05
AL (mm)	0.40 (0.34 to 0.47)	<0.01	0.18 (0.07 to 0.29)	<0.01	0.14 (0.03 to 0.26)	<0.05
CCT (μm)	4.03 (1.97 to 6.08)	<0.01	2.43 (−1.29 to 6.16)	0.20	3.41 (−0.76 to 7.58)	0.11
ACD (mm)	0.05 (0.04 to 0.07)	<0.01	0.02 (−0.01 to 0.05)	0.17	0.02 (−0.02 to 0.05)	0.34
LT (mm)	−0.04 (−0.05 to −0.02)	<0.01	−0.01 (−0.03 to 0.02)	0.57	−0.01 (−0.03 to 0.02)	0.75
VCD (mm)	0.38 (0.32 to 0.44)	<0.01	0.17 (0.06 to 0.27)	<0.01	0.13 (0.02 to 0.25)	<0.05
CC (mm)	0.01 (−0.01 to 0.03)	0.13	0.01 (−0.02 to 0.04)	0.41	0.01 (−0.03 to 0.04)	0.81
AL/CC ratio	0.05 (0.04 to 0.06)	<0.01	0.02 (0.01 to 0.03)	<0.01	0.02 (0.01 to 0.03)	<0.05
Weight (per 10 kg)						
SER (D)	−0.65 (−0.79 to −0.51)	<0.01	−0.21 (−0.39 to −0.03)	<0.05	−0.18 (−0.36 to 0.01)	0.07
AL (mm)	0.46 (0.38 to 0.55)	<0.01	0.16 (0.05 to 0.26)	<0.01	0.15 (0.04 to 0.26)	<0.01
CCT (μm)	5.56 (2.93 to 8.20)	<0.01	3.68 (0.06 to 7.29)	<0.05	4.44 (0.42 to 8.47)	<0.05
ACD (mm)	0.05 (0.03 to 0.07)	<0.01	−0.01 (−0.03 to 0.02)	0.90	−0.01 (−0.03 to 0.03)	0.87
LT (mm)	−0.04 (−0.05 to −0.02)	<0.01	0.01 (−0.02 to 0.02)	0.95	0.01 (−0.02 to 0.03)	0.96
VCD (mm)	0.44 (0.36 to 0.53)	<0.01	0.16 (0.06 to 0.27)	<0.01	0.15 (0.04 to 0.26)	<0.01
CC (mm)	0.03 (0.01 to 0.05)	<0.05	0.02 (−0.01 to 0.05)	0.11	0.02 (−0.01 to 0.05)	0.14
AL/CC ratio	0.05 (0.04 to 0.06)	<0.01	0.01 (−0.01 to 0.02)	0.10	0.01 (−0.01 to 0.02)	0.16
BMI (per 10 kg/m^2)						
SER (D)	−0.64 (−1.15 to −0.13)	<0.05	−0.26 (−0.73 to 0.20)	0.26	−0.27 (−0.74 to 0.20)	0.25
AL (mm)	0.53 (0.21 to 0.84)	<0.01	0.20 (−0.07 to 0.47)	0.15	0.23 (−0.05 to 0.50)	0.10
CCT (μm)	9.50 (0.35 to 18.65)	<0.05	6.37 (−2.79 to 15.53)	0.17	7.19 (−2.87 to 17.25)	0.16
ACD (mm)	0.03 (−0.05 to 0.10)	0.50	−0.03 (−0.10 to 0.04)	0.46	−0.02 (−0.10 to 0.05)	0.52
LT (mm)	−0.02 (−0.08 to 0.03)	0.42	0.01 (−0.05 to 0.07)	0.79	0.01 (−0.06 to 0.07)	0.86
VCD (mm)	0.55 (0.24 to 0.85)	<0.01	0.23 (−0.03 to 0.50)	0.09	0.25 (−0.03 to 0.52)	0.08
CC (mm)	0.06 (−0.01 to 0.14)	0.09	0.04 (−0.03 to 0.11)	0.25	0.06 (−0.02 to 0.14)	0.13
AL/CC ratio	0.04 (0.01 to 0.08)	<0.05	0.01 (−0.02 to 0.04)	0.58	0.01 (−0.03 to 0.04)	0.67

Model 1 constructs based on crude data. In the next two models, we controlled, in turn, for age and gender or for age, gender, parental myopia, family income, reading and writing distance and time spent outdoors.
*Each value represents a separate regression model, with height, weight or BMI used as the independent variable, the refraction or individual ocular biometrics used as the dependent variable, either alone or with various confounders. Data in parentheses represent the 95% CI.
ACD, anterior chamber depth; AL, axial length; BMI, body mass index; CC, corneal curvature; CCT, central corneal thickness; LT, lens thickness; SER, spherical equivalent refraction; VCD, vitreous chamber depth.

previous studies,[17 28] it can lead to recall bias. Second, the representativeness of the participants in this study may be affected to some extent because the participants were volunteers. Although there were no significant differences in nearly all basic characteristics between participants and those excluded, individuals who were included were older, which may have resulted in overestimation of the prevalence of myopia in our study. Third, all of the data collected in this study were cross-sectional in nature and do not allow an evaluation of causality. Therefore, whether the conclusions drawn from this study are applicable to longitudinal relationships remains uncertain. Additionally, the significant correlation observed in our study needs to be interpreted carefully because of the small sample size. It is important to avoid making strong conclusions about these associations, regardless of whether the results were positive. A larger sample size study is needed in the future to validate our conclusions. Despite these limitations, we believe that our study provides a valuable reference regarding the associations between anthropometric indicators and both refraction and ocular biometrics in Chinese schoolchildren aged 6–15 years old.

In conclusion, both higher heights and heavier weights were associated with longer ALs, deeper VCDs, higher AL/CC ratios and more myopic refractions during the early period of adolescent growth after controlling for age, gender, parental myopia, family income, reading and writing distance and time spent outdoors. The results of this study support the idea that a shared mechanism may

Table 5 Age-specific results of the associations of anthropometric indicators with both refraction and ocular biometrics

	6–8 years old (n=170)	9–11 years old (n=158)	12–15 years old (n=154)
	b	*b*	*b*
Height (per 10 cm)			
SER (D)	−0.31 (−0.59 to −0.03)*	−0.48 (−0.71 to −0.24)**	0.35 (−0.52 to 1.22)
AL (mm)	0.17 (−0.02 to 0.35)	0.25 (0.11 to 0.38)**	−0.25 (−0.69 to 0.18)
CCT (µm)	2.01 (−5.59 to 9.60)	0.77 (−3.82 to 5.36)	10.49 (−5.41 to 26.39)
ACD (mm)	0.04 (−0.02 to 0.10)	0.03 (−0.01 to 0.06)	−0.09 (−0.17 to −0.01)
LT (mm)	−0.03 (−0.08 to 0.02)	−0.01 (−0.04 to 0.01)	0.07 (−0.02 to 0.15)
VCD (mm)	0.18 (−0.004 to 0.36)	0.23 (0.09 to 0.36)**	−0.23 (−0.69 to 0.23)
CC (mm)	−0.01 (−0.07 to 0.05)	−0.01 (−0.05 to 0.03)	0.01 (−0.09 to 0.12)
AL/CC	0.03 (0.003 to 0.05)*	0.04 (0.02 to 0.05)**	−0.04 (−0.09 to 0.02)
Weight (per 10 kg)			
SER (D)	−0.37 (−0.67 to −0.07)*	−0.48 (−0.74 to −0.23)**	0.39 (−0.23 to 1.01)
AL (mm)	0.13 (−0.08 to 0.33)	0.29 (0.15 to 0.44)**	−0.09 (−0.41 to 0.22)
CCT (µm)	1.43 (−6.93 to 9.79)	3.00 (−1.99 to 7.99)	10.83 (−0.38 to 22.04)
ACD (mm)	−0.002 (−0.06 to 0.06)	0.03 (−0.01 to 0.07)	−0.06 (−0.11 to 0.002)
LT (mm)	0.02 (−0.03 to 0.08)	−0.03 (−0.06 to 0.001)	0.02 (−0.05 to 0.08)
VCD (mm)	0.11 (−0.09 to 0.31)	0.29 (0.14 to 0.44)**	−0.06 (−0.39 to 0.28)
CC (mm)	0.02 (−0.05 to 0.08)	0.003 (−0.04 to 0.04)	0.04 (−0.04 to 0.11)
AL/CC	0.01 (−0.01 to 0.04)	0.04 (0.02 to 0.06)**	−0.03 (−0.07 to 0.01)
BMI (per 10 kg/m^2)			
SER (D)	−0.46 (−1.10 to 0.17)	−0.63 (−1.38 to 0.13)	0.96 (−1.02 to 2.93)
AL (mm)	0.06 (−0.36 to 0.48)	0.47 (0.05 to 0.90)*	0.03 (−0.98 to 1.03)
CCT (µm)	0.84 (−16.31 to 17.99)	9.14 (−5.10 to 23.37)	28.47 (−7.47 to 64.41)
ACD (mm)	−0.07 (−0.19 to 0.06)	0.04 (−0.07 to 0.15)	−0.10 (−0.28 to 0.09)
LT (mm)	0.10 (−0.01 to 0.21)	−0.07 (−0.16 to 0.01)	−0.03 (−0.23 to 0.17)
VCD (mm)	0.01 (−0.40 to 0.43)	0.51 (0.08 to 0.93)*	0.15 (−0.91 to 1.21)
CC (mm)	0.05 (−0.09 to 0.19)	0.03 (−0.08 to 0.14)	0.13 (−0.11 to 0.37)
AL/CC	−0.01 (−0.06 to 0.04)	0.05 (−0.003 to 0.11)	−0.05 (−0.17 to 0.08)

Each value represents a separate regression model with height, weight or BMI used as the independent variable and the refraction or individual ocular biometrics used as the dependent variable. We controlled for gender, parental myopia, family income, reading and writing distance and time spent outdoors. Data in parentheses represents the 95% CI.
*P<0.05; **p<0.01.
ACD, anterior chamber depth; AL, axial length; BMI, body mass index; CC, corneal curvature; CCT, central corneal thickness; LT, lens thickness; SER, spherical equivalent refraction; VCD, vitreous chamber depth.

regulate the coordinated growth of body and eye size in children.

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